Ecology, age and growth of *Atherina boyeri* and *Atherina presbyter* in the Ria de Aveiro, Portugal

by

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ABSTRACT. - *Atherina boyeri* Risso, 1810 and *A. presbyter* Cuvier, 1829 show similar morphology and anatomy, which makes difficult the species identification by conventional tools. The ecological behaviour and biological features are markedly distinct in both species. In the Ria de Aveiro, a typical coastal estuarine lagoon, *A. boyeri* and *A. presbyter* are among the four most abundant species. Ecology, age and growth of both species were compared from sampling carried out from November 1998 to November 1999 at nine sites covering all the lagoon area. *A. boyeri*, a resident species, occurred in different stages of the lifespan in the entire lagoon area. Juveniles occurred dispersedly in space, with no apparent abiotic preference. In winter, older adults (2^+-3^+) occurred with high abundance at the edges of the lagoon, in deep regions with low temperature, salinity and transparency, and high dissolved oxygen and pH. During autumn, the juveniles of marine juvenile migrant species, *A. presbyter*, were confined to deep regions of the lagoon edges, with low temperature, salinity and transparency, high dissolved oxygen, and neutral pH. In mid-spring, the adults occurred with high abundance near the sea, in a narrow range of all abiotic parameters. The length frequency distribution, and the fish and otolith length-weight relationships were significantly different in both species. *A. boyeri* reached 11.6 cm in 3 years, while *A. presbyter* reached 15.1 cm in 4 years. For the same length, *A. boyeri* (b = 3.35) was heavier than *A. presbyter* (b = 3.09). The von Bertalanffy growth parameters for *A. boyeri* were $L_\infty = 11.6$ cm, k = 0.099 $year^{-1}$, and $t_0 = -3.797$ years and for *A. presbyter* were $L_\infty = 15.8$ cm, k = 0.138 $year^{-1}$, and $t_0 = -2.501$ years. *A. boyeri* and *A. presbyter* grew faster during the first year of life (66% and 43% of maximum size, respectively). The observed and theoretical length and age were quite similar for both species and the values close to those in different Atlantic and Mediterranean systems.

RÉSUMÉ. - Écologie, âge et croissance d'*Atherina boyeri* et d'*Atherina presbyter* dans le Ria de Aveiro, Portugal.

Atherina boyeri Risso, 1810 et *A. presbyter* Cuvier, 1829 ont une morphologie et une anatomie semblables, ce qui rend l'identification des espèces par les outils conventionnels difficile. Le comportement écologique et la biologie sont très différents entre les deux espèces. Dans le Ria de Aveiro, une lagune côtière estuarienne typique, *A. boyeri* et *A. presbyter* sont parmi les quatre espèces les plus abondantes. L'écologie, l'âge et la croissance des deux espèces ont été comparés à partir de prélèvements effectués de novembre 1998 à novembre 1999, dans neuf stations couvrant toute la lagune. *A. boyeri*, espèce résidente, est présente à différentes étapes du cycle de vie dans toute la lagune. Les juvéniles sont dispersés dans l'espace, sans préférence abiotique apparente. Les adultes plus âgés (2^+-3^+) ont été abondants aux bords de la lagune, en hiver, dans des régions profondes avec de basses température, salinité et transparence, et avec des hautes valeurs d'oxygène dissous et de pH. Les juvéniles d'*A. presbyter*, espèce migratrice marine, ont été confinés aux régions profondes des bords de lagune, pendant l'automne, avec de basses température, salinité et transparence, de fortes valeurs d'oxygène dissous, et avec un pH neutre. Les adultes ont été abondants près du débouché de la lagune avec la mer, au printemps, dans une gamme étroite de tous les paramètres abiotiques. La distribution de fréquence de longueur, et les relations longueur-poids des poissons et des otolithes ont été significativement différentes entre les deux espèces. *A. boyeri* a atteint 11,6 cm en 3 ans, tandis que *A. presbyter* a atteint 15,1 cm en 4 ans. Pour la même longueur, *A. boyeri* (b = 3,35) a été plus lourde qu' *A. presbyter* (b = 3,09). Les paramètres de croissance de von Bertalanffy pour *A. boyeri* ont été $L_\infty = 11{,}6$ cm, k = 0,099 an^{-1}, et $t_0 = -3{,}797$ ans et pour *A. presbyter* $L_\infty = 15{,}8$ cm, k = 0,138 an^{-1}, et $t_0 = -2{,}501$ ans. *A. boyeri* et *A. presbyter* se sont développés plus rapidement pendant la première année de vie (66% et 43% de la taille maximum, respectivement). La longueur et l'âge théoriques observés ont été semblables pour les deux espèces avec des valeurs proches de celles qui sont observées dans différents systèmes atlantiques et méditerranéens.

Key words. - Atherinidae - *Atherina boyeri* - *Atherina presbyter* - ANE - Portugal - Ria de Aveiro - Ecological behaviour - Life history - Sympatric species.

The atherinid fish species, big-scale sand smelt *Atherina boyeri* Risso, 1810 and sand smelt *A. presbyter* Cuvier, 1829, exhibit very similar morphology and anatomy. The taxonomic identification by the common morphometric characteristics, as head length, number of scales in longitudinal series, and number of vertebrae (Whitehead *et al.*, 1986; Bauchot and Pras, 1987), is ambiguous and leads to some doubts. Bamber and Henderson (1985), inclusively, proposed the synonymy of *A. boyeri* with *A. presbyter*. However, recent studies approaching genetic and biological aspects have demonstrated differences between these two populations, consistent with the existence of two species (Creech, 1991, 1992). The species comprise distinct ecology behaviour and different geographical distribution. *A. boyeri* was described as a truly resident species, preferring littoral, estuaries, lagoons, and inshore areas forming land-locked populations where it spends its entire life (Elliott and Dewailly, 1995; Whitehead *et al.*, 1986). It is a very euryhaline spe-

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cies, from hyperhaline water (77 psu, in Corsica) to freshwater (Whitehead *et al.*, 1986; Rosecchi and Crivelli, 1992, 1995; Leonardos and Sinis, 2000; Leonardos, 2001). The distribution area includes the Mediterranean and adjacent seas, the Black Sea and the Atlantic, from south of Spain to Morocco and Madeira. Isolated populations can be found on coasts of England and Netherlands (Whitehead *et al.*, 1986; Rosecchi and Crivelli, 1992, 1995; Leonardos and Sinis, 2000; Leonardos, 2001). *A. presbyter* was described as a marine juvenile migrant species, which uses estuaries and coastal lagoons primarily as a nursery ground. Much of its adult life is spent at sea, but it often returns seasonally to the estuary (Elliott and Dewailly, 1995). It occurs along the European and African coasts of the Atlantic Ocean, from the Kattegat (rare) and Scotland to Morocco, and around Madeira, Canaries and Cape Verde Islands. It is rare in the Mediterranean, found off Gibraltar, France and Tunisia (Whitehead *et al.*, 1986; Lorenzo and Pajuelo, 1999; Pajuelo and Lorenzo, 2000).

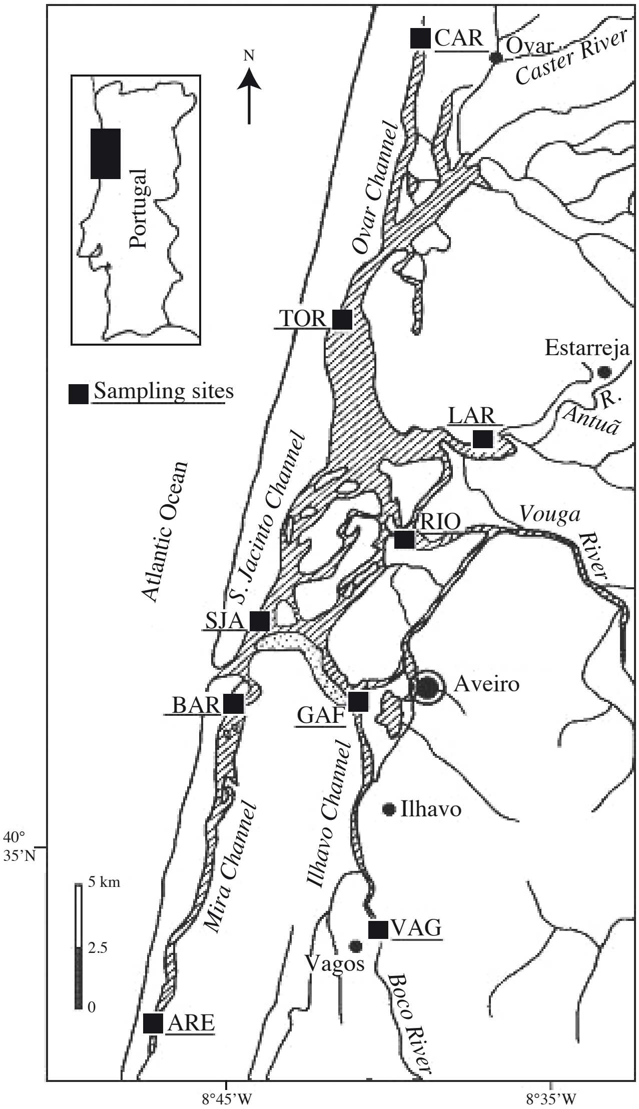

Figure 1. - Map of the Ria de Aveiro lagoon showing sampling sites. CAR - Carregal; TOR - Torreira; LAR - Laranjo; RIO - Rio Novo de Príncipe; SJA - São Jacinto; BAR - Barra; GAF - Gafanha; VAG - Vagos; ARE - Areão. *[Carte de la lagune du Ria de Aveiro montrant les sites d'échantillonnage.]*

The information about atherinids is scarce and mainly focuses on biological aspects such as age, growth and mortality (Fernandez-Delgado *et al.*, 1988; Creech, 1992; Rosecchi and Crivelli, 1992; Rosecchi and Crivelli, 1995; Lorenzo and Pajuelo, 1999; Leonardos and Sinis, 2000; Pajuelo and Lorenzo, 2000; Leonardos, 2001), and morphological, morphometric, biochemical and genetic characteristics (Bembenuti, 1993; Trabelsi *et al.*, 1994; Vasil'eva, 1994; Conglu *et al.*, 1997; Focant *et al.*, 1999; Klossa-Kilia *et al.*, 2002; Trabelsi *et al.*, 2002a, 2002b).

Only *A. presbyter* was referred to the Portuguese coast, besides Ria de Aveiro, namely in Tagus estuary (Costa, 1986; Costa and Bruxelas, 1989), in Sado estuary (Cabral, 1999) and in Ria Formosa (Monteiro *et al.*, 1987, Santos *et al.*, 1996). *A. boyeri* was turned visible since 1992 in the Ria de Aveiro (Rebelo, 1992; Cruz and Rebelo, 2000; Rebelo and Pombo, 2001; Pombo and Rebelo, 2002; Pombo *et al.*, 2002a-c), so before that only *A. presbyter* was described from the lagoon (Osório, 1912; Nobre *et al.*, 1915; Arruda *et al.*, 1988). Nowadays, both species are comprised in the four most abundant species of the lagoon.

This paper intends to distinguish two atherinids species (*A. boyeri* and *A. presbyter*) through their ecology, age and growth patterns, according to their occurrence in a typical estuarine coastal lagoon. These features intend to be a useful contribution to the identification of atherinids besides the wide used traditional taxonomy.

MATERIAL AND METHODS

Study area

The Ria de Aveiro (Fig. 1), on the west coast of Portugal, is an estuarine lagoon with a maximum length of 45 km and maximum width of 11 km that delimit a total area between 43 km^2 (low tide) and 47 km^2 (high tide). The water volume is 70 million m^3, with an oceanic tidal contribution of between 25 million m^3 (neap-tides) to 90 million m^3 (higher spring tides). Four rivers (Vouga, Antuã, Caster and Boco) and uncounted streams flow between 3 m^3.s^{-1} and 60 m^3.s^{-1}, due to the influence of seasonal precipitations and run-off patterns. The depth varies between 0.6 m and 10.0 m. The mean substratum is silt, however sandy close to the lagoon's mouth and with immerses vegetation in the north extreme. The industrial and fishing ports, and the industries and population in the watershed are sources of three main pollution types: organic and chemical pollution, chemical pollution, and microbial contaminants (Barrosa, 1980; Lucas *et al*., 1986; Borrego *et al*., 1994).

The particular abiotic attributes of this system – shallowness, high turbidity, nature of substract, temperature, salinity and oxygen – associated with its high biotic productivity, offer excellent conditions for colonisation by many species of fish, especially teleosts (Potter *et al*., 1990; Rebelo, 1992).

The Ria de Aveiro is economically important because of its fisheries, industry, agriculture, sea farming, tourism and, more recently, aquaculture. With a good communication with the sea that guarantees seasonally the fish recruitment, the lagoon is an area of considerable fish exploitation (commercial and recreational). Previous fish studies in the Ria de Aveiro (Osório, 1912; Nobre *et al*., 1915; Arruda *et al*., 1988; Rebelo, 1992; Pombo and Rebelo, 2002; Rebelo and Pombo, 2001; Pombo *et al*., 2002b) contributed to the knowledge about the dynamics and the evolution of the fish populations inside the lagoon and its relationship with the adjacent ocean.

Field sampling

Fish were collected monthly, from November 1998 to November 1999, at nine selected sites (Fig. 1): near the mouth of the lagoon (BAR, GAF and SJA); at the edges of the main channels (ARE, CAR and VAG); in the main freshwater area, highly organically enriched (RIO); in the region of higher levels of industrial pollution (LAR), and approximately in the middle of the longest channel (TOR).

At each site and each month, 3 non-overlapping replicate samples were taken at low spring tide, over the five days of the new moon. The total area enclosed by the gear was approximately 193 m^2 in each trawl. A 'chincha' or traditional beach-seine net (Nobre *et al*., 1915) was used to sample fish. The 'chincha' gear used was almost rectangular in shape and composed by a central bag (a 'cod-end', 295 cm of length and 145 cm of wide), two lateral wings (12 m of length each, the width decreasing along the net, reaching 50 cm at the edge), two ropes (6.1 m each), floating buoys at the top and ceramic weights at the bottom of the net. The stretched mesh sizes in the gear were 19 mm at the wings, 17 mm at the cod mouth, 16 mm at the cod sleeve, and 10 mm at the cod-end. The end of the net was fixed to the margin and the remainder was trawled in a semi-circle thus retaining within the cod-end all the fish from the area. The net efficiency is estimated at 90% (Elliott and Hemingway 2002).

Abiotic parameters (temperature and dissolved oxygen) were recorded with an oxygen meter (CONSORT Z621), the salinity was recorded with a refractometer (ATAGO), pH was recorded with a pH meter (WTW pH 330/SET-2), and the percentage of water transparency was estimated based on turbidity and Secchi depth, according to Yáñez-Arancibia (1983).

Fish and otolith use

Fish were preserved by freezing. At the laboratory, specimens were identified using to the taxonomic keys of Whitehead *et al*. (1986) and Bauchot and Pras (1987). The species identification was made by at least two investigators and only coincided results were considered to minimise possible errors of identification.

Fish were measured to the nearest 0.1 cm (total length, L), and weighed to the nearest 0.1 g (total fresh weight, W). The total abundance of each species in terms of fish numbers captured in the three replicates was recorded in each site each month.

Otoliths and scales were removed from fish obtained in aleatory sub-samples and stored dry in properly labelled envelopes. The scales were removed from the base of the pectoral fin in the longitudinal line. Otoliths were measured, from the anterior tip to the posterior projection, to the nearest 0.1 mm, and weighed, to the nearest 0.1 mg. Right otoliths were examined, except in abnormal cases (i.e. broken), where the left was examined, under reflected light with a stereomicroscope (OLYMPUS SZ60-PT) having a micrometer eyepiece. The number of opaque zones (winter rings, appearing bright under reflected light) and the presence of a marginal translucent zone (summer rings, appearing dark under reflected light) were registered. Otoliths were compared to scale ageing readings made by two investigators and only coincided readings were considered to minimise observation errors.

Data analysis

The threshold values of abiotic parameters (temperature, salinity, dissolved oxygen, pH, depth and transparency) were opposed with space abundances of *A. boyeri* and *A. presbyter*. The log-transforming abundance data were used to minimize large differences recorded.

The length distributions of both species were compared by Kolmogorov-Smirnov (K-S) two-sample test (Sokal and Rohlf, 1995; Zar, 2000).

The fish length-weight relationship was calculated using all individuals sampled, following the Gulland's equation (Gulland, 1969): $W = a L^b$, where W is the total body weight (g), L is the total length (cm), and a and b are the regression coefficients. The same equation was adopted for otoliths length-weight relationship. The comparison of slopes of fish length-weight and the otolith length-weight relationships was carried out by using the Student's t test with log-transforming data: $t : (b_1 - b_2) / (S_{b1 - b2})$, where b_1 and b_2 are the regression coefficients and S_{b1-b2} is the standard error of the difference between regression coefficients (Zar, 2000).

The difference of the otolith age groups was composed for each species by Kruskal-Wallis (K-W) one-way analysis.

Age growth was expressed in terms of the von Bertalanffy equation (von Bertalanffy, 1938): $L_t = L_\infty [1-e^{-k(t-t_0)}]$, where L_t is the fish length at age t, L_∞ is the maximum asymptotic length, *k* is the growth curvature parameter, and t_0 is the computed age where the fish has no growth both in length and weight. The growth parameters were estimated by the software ELEFAN I, included in FISAT (Pauly, 1987).

RESULTS

Abiotic parameters

The Ria de Aveiro is influenced by a maritime temperate climate. The seasonality of the air temperature and rainfall is well marked. The warm period occurred during summer (from June to September) and the cold period occurred during the late autumn and winter (from December to February). The water temperature ranged from 7.6ºC, at VAG, in winter, to 26.7ºC, at CAR, in summer. The salinity ranged from freshwater (0.0 psu), at RIO, in winter, to marine water (35.0 psu) at the mouth of the lagoon and at TOR, in summer. The dissolved oxygen ranged from 4.8 mg l^{-1}, in autumn, at BAR, to 13.2 mg l^{-1}, at CAR and VAG, both in winter. The pH ranged from 6.9, at LAR, in autumn, to 8.6, at ARE, in winter. The depth ranged from 0.6 m, at ARE, in summer, to 5.4 m, at RIO, in winter, and the opposite occurred with the transparency, which ranged from 4.4%, at VAG, in summer, to 100.0%, at TOR, in winter.

Abundance of fish and abiotic environment

In spite of a general distribution in all the lagoon area, the two species showed different spatial preferences, associated to particular abiotic environment. *A. boyeri* occurred with high abundance (more than 180 specimens, 7% of total abundance) during winter at the edges of the lagoon (CAR and VAG), where the water turnover was lower. The highest abundance was recorded in periods where the abiotic parameters – temperature (7.6-12.0ºC), salinity (10.0-21.0 psu) and transparency (13.7-21.7%) – were lower than the observed for *A. presbyter* occurrence. *A. presbyter* occurred mainly (more than 40% of total abundance) in areas with high levels of chemical and oil pollution (LAR and VAG) and near the lagoon mouth (GAF). The highest abundance was recorded in periods with relative high values of the temperature (11.2-13.5ºC), salinity (28.0-32.0 psu) and transparency (20.7-28.6%).

The dissolved oxygen, pH and depth parameters appeared not contributing to the distinction of the two populations. *A. boyeri* and *A. presbyter* occurred with high abundance in periods with similar values of dissolved oxygen (4.8-9.8 mg l^{-1} and 5.4-8.3 mg l^{-1}, respectively), pH (7.2-8.3 and 7.3-8.0, respectively) and depth (3.4-4.4 m and 3.2-4.5 m, respectively).

Occurrence per age

The lifespan migration patterns inside the lagoon were noticeably different for *A. boyeri* and *A. presbyter*. Both juveniles (0^+) and older adults (3^+) of *A. boyeri* (Tab. I) occurred close the lagoon mouth (BAR and GAF) and throughout the main channel (TOR). However, the highest abundance was recorded at the north (CAR) and south (VAG) edges of the lagoon, in winter, with specimens mainly belonging to the 2^+-age class. Younger specimens (0^+-1^+) of *A. presbyter* (Tab. I) occurred mainly at the south edge of the lagoon (VAG). Older fish (2^+-3^+) occurred more abundantly close to the mouth of the lagoon (BAR and GAF), during the reproductive migration in mid-spring. High abundance during all the year was recorded in a particular site (GAF) near the sea.

Table I. - Abundance (number of fish, length (cm TL)), weight and age ranges of *Atherina boyeri* and *A. presbyter* per sampling site (SS) and in all the Ria de Aveiro lagoon (Total). *[Abondance (nombre de poissons, taille (cm TL)), tranches d'âge et de poids pour* Atherina boyeri *et* A. presbyter *par site d'échantillonnage (SS) dans toute la lagune du Ria de Aveiro (Total).]*

A. boyeri										
SS	ARE	BAR	CAR	GAF	LAR	RIO	SJA	TOR	VAG	Total
Abundance	101	42	1093	158	90	73	93	60	793	2503
Length (cm TL)	4.2 - 9.7	1.56 - 9.00	4,3 - 9.6	2.7 - 11.1	3.4 - 10.6	4.1 - 9.2	4.4 - 11.6	2.9 - 7.7	3.9 - 10.5	1.6 - 11.6
Weight (g)	0.4 - 7.3	0.1 - 4.2	0.5 - 5.6	0.1 - 9.1	0.1 - 8.8	0.5 - 5.9	0.4 - 11.5	0.1 - 2.6	0.2 - 8.4	0.1 - 11.5
Age (years)	0+ - 3+	0+ - 3+	0+ - 3+	0+ - 3+	0+ - 3+	0+ - 3+	0+ - 3+	0+ - 3+	0+ - 3+	0+ - 3+

A. presbyter										
SS	ARE	BAR	CAR	GAF	LAR	RIO	SJA	TOR	VAG	Total
Abundance	12	92	46	535	133	16	96	81	158	1169
Length (cm TL)	5.00 - 8.8	6.1 - 13.3	7.4 - 13.5	5.2 - 13.4	6.1 - 15.1	6.8 - 12.1	5.1 - 12.6	4.1 - 13.6	5.6 - 13.6	4.1 - 15.1
Weight (g)	0.8 - 4.6	1.3 - 16.2	2.6 - 19.0	0.8 - 17.8	1.2 - 27.9	1.8 - 13.4	0.8 - 13.4	0.4 - 17.2	1.1 - 17.9	0.4 - 27.9
Age (years)	0+ - 1+	0+ - 3+	1+ - 3+	0+ - 3+	0+ - 4+	0+ - 2+	0+ - 2+	0+ - 3+	0+ - 3+	0+ - 4+

Length frequency distribution

The length composition (Fig. 2) significantly varied between the two species (K-S test: d max = 0.4, $p < 0.001$). For *A. boyeri* the minimum and maximum lengths were 1.6 cm and 11.6 cm, respectively, while for *A. presbyter* were 4.1 cm and 15.1 cm, respectively. The most abundant length classes were 6.5-8.5 cm, for *A. boyeri*, and 10.5-12.5 cm, for *A. presbyter*.

Length-weight relationship

Fish length-weight relationship, an expression of growth, was established separately to the two species. Both equations showed that the weight grew allometrically with the length; the b values ($b > 3$) showed that species grew faster in weight than in length (Tesch, 1971). For the same length, *A. boyeri* ($b = 3.4$) became heavier than *A. presbyter* ($b = 3.1$). The comparative analysis of the regressions revealed statistically different slopes ($t = 28.02$, $p < 0.001$).

Otolith length-weight relationship

The Gulland's growth equation to fish length and weight revealed to be fitted to the otoliths growth. *A. boyeri*'s otoliths grew faster in length than in weight ($b = 2.9$). The opposite occurred for *A. presbyter* ($b = 3.1$). The comparative analysis of the otolith regressions revealed statistically different slopes ($t = 6.15$, $p < 0.001$).

The otolith growth followed the fish growth. The smallest fish (3.4 cm for *A. boyeri* and 4.6 cm for *A. presbyter*) was set to match with the smallest otolith length (1.3 and 1.8 mm respectively), and the longest fish (11.6 cm for *A. boyeri* and 15.1 cm for *A. presbyter*) was set to match with the longest otolith length (4.3 and 5.4 mm respectively). The relationship between fish length and otolith length was similar in both species ($t = -3.760$, $p > 0.05$), *i.e.*, the otolith length attends the fish length at the same proportions for both species.

Age and growth

Intending to compare the length-age growth, the otolith lengths were divided into one-year age groups. In both species the otolith lengths were statistically different between age groups ($H = 120.62$, $p < 0.001$ for *A. boyeri* and $H = 306.30$, $p < 0.001$ for *A. presbyter*). The mean incremental growth per age group was higher for *A. boyeri*, between 0.6 cm and 1.4 cm, than for *A. presbyter*, between 1.8 cm and 2.6 cm (Fig. 3). The proportion of growth was calculated for each age group. The first year of life growth for *A. boyeri* and *A. presbyter* (66% and 43%, respectively) was remarkably faster than the consequent age groups. In both species, the 2^+ age group was found to be the most abundant, followed by 1^+, 0^+ and 3^+ age groups. The 4^+ age group was just found for *A. presbyter*, but only in a unique specimen, though it is not represented in figure 3.

The von Bertalanffy growth equation was established for *A. boyeri* and *A. presbyter* (Tab. II). In both species, the theoretical lengths for *A. boyeri*, 11.6 cm, and for *A. presbyter*, 15.8 cm, were realistic and agreed to the largest specimen caught during this study, 11.6 cm and 15.1 cm, respectively. Theoretical length values were compared with the fish length collected from nature (Tab. III) and found to coincide.

DISCUSSION

The ecotone Ria de Aveiro is strongly influenced by the weather, showing a large range of abiotic parameters. The constant influences of marine and freshwaters, and the seasonal changes in temperature, rainfall, and wind, together produce high summer and low winter values of water temperature and salinity, with the reverse for oxygen. The pH is influenced by pollution, and transparency varies according to depth (Rebelo, 1992; Anonymous, 1994; Borrego *et al.*, 1994). The complexity of the system allows the occurrence of a high diverse fish community, grouped in distinct eco-

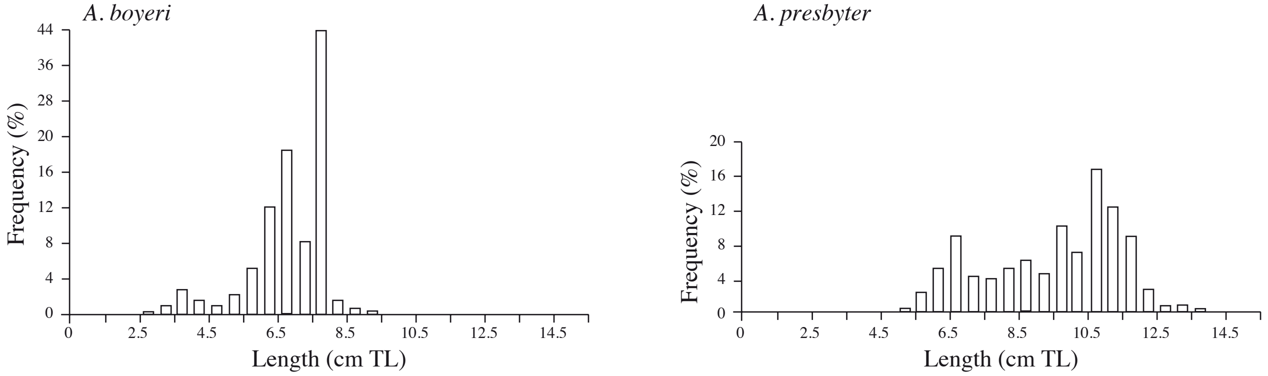

Figure 2. - Length frequency (cm TL) distribution of *A. boyeri* (N = 2503) and *A. presbyter* (N = 1169). *[Distribution de la fréquence de taille (cm TL) de* Atherina boyeri *(N = 2503) et de* A. presbyter *(N = 1169).]*

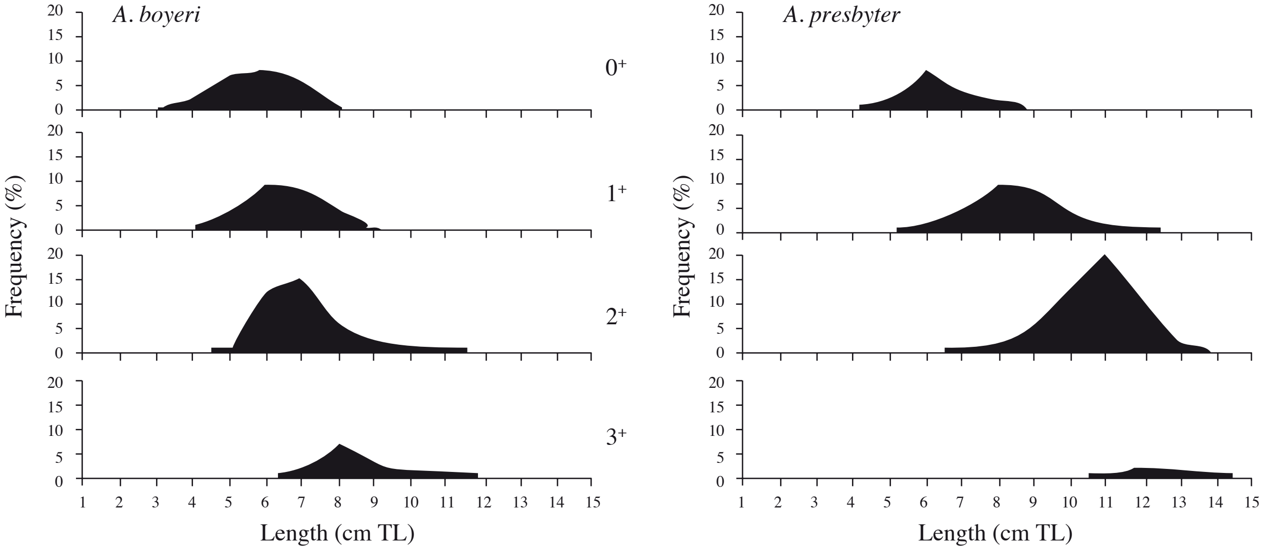

Figure 3. - Length (cm TL) and age frequency distribution of *A. boyeri* (N = 350) and *A. presbyter* (N = 477). *[Distribution de la fréquence en taille (cm TL) et en âge de* A. boyeri *(N = 350) et de* A. presbyter *(N = 477).]*

logical guilds. The sedentary species, including *A. boyeri*, and the marine juvenile migrant species, including *A. presbyter*, comprise the most representative lagoon guilds (Rebelo, 1992; Elliott and Dewailly, 1995; Pombo *et al.*, 2002b).

A. boyeri and *A. presbyter*, in spite of being always present in space and time, showed separate abiotic preferences. *A. boyeri* mainly occurred at lower abiotic limits than *A. presbyter* for temperature, salinity and transparency.

Both species showed separate ecological behaviours of abundance and migration inside the lagoon, associated to the abiotic environment. *A. boyeri* was confined to the edges of the lagoon, during the winter, for spawning (Fernández-Delgado *et al.*, 1988; Rosecchi and Crivelli, 1992). Individuals of 7-8 cm of total length (2-3 years) appeared with a large abundance, at deep regions with low temperature, salinity and transparency, and high dissolved oxygen and pH, mostly at the north and south edges of the lagoon. In the remaining time of the year, specimens occurred dispersedly in space, with no apparent abiotic preference.

Table II. - Comparison of von Bertalanffy parameters established for *Atherina boyeri* (N = 350) and *A. presbyter* (N = 477). *[Comparaison des paramètres de von Bertalanffy établis pour* Atherina boyeri *(N = 350) et* A. presbyter *(N = 477).]*

	L_∞ (cm TL)	k (year $^{-1}$)	t_0 (years)
A. boyeri	11.6	0.099	-3.797
A. presbyter	15.8	0.138	-2.501

In general, *A. presbyter* occurred with almost twice-lower abundance than *A. boyeri*. The species showed an evident selective spatial distribution with the age. Juveniles occurred with high abundance at deep regions of the lagoon edges, during autumn, with low temperature, salinity and transparency, high dissolved oxygen, and neutral pH. The high vegetation and productivity of these regions provided high food sources and refuges to this critical lifespan period. In the second year of life, fish began to migrate, to the entrance area when they were getting maturity for spawning (Pajuelo and Lorenzo, 2000). With the increasing size (10-15 cm) and age (2-3 years) adult fish occurrence was restricted, with high abundance, to a particular area close to the sea (Rebelo, 1992; Pombo and Rebelo, 2002; Cruz and Rebelo, 2000; Pombo *et al.*, 2002c). That high adult abundance occurred associated to marine levels of salinity, high values of temperature, depth and transparency, neutral pH and low dissolved oxygen.

Biological features, as length, weight, growth and age were distinctive in both species. The length composition was markedly different. *A. boyeri* was smaller but heavier than *A.*

Table III. - Comparison of observed length values (cm TL) of the samples and theoretical calculated length values, according to age groups of *Atherina boyeri* and *A. presbyter*. *[Comparaison des tailles (cm TL) des échantillons et des tailles théoriques calculées, par groupes d'âge de* Atherina boyeri *et* A. presbyter.*]*

Age groups	*A. boyeri*				*A. presbyter*			
	N	Observed	Theoretical	% Growth	N	Observed	Theoretical	% Growth
0^+	79	5.6	5.5	65.5	71	6.5	6.6	43.1
1^+	90	6.2	6.6	10.3	140	8.5	8.7	13.0
2^+	131	7.1	7.6	7.4	238	10.7	10.5	15.0
3^+	50	8.6	8.5	16.8	27	12.5	12.1	11.7
4^+	-	-	-	-	1	15.1	13.4	17.2

Table IV. - Maximum age, number of specimens sampled (*N*), length-weight relationship parameters (*a, b*) and von Bertalanffy parameters (L_∞, K, t_0) of *Atherina boyeri* and *A. presbyter* in different systems of Atlantic and Mediterranean (adapted from Leonardos and Sinis, 2000). *[Âge maximal, nombre de spécimens* (N)*, paramètres de la relation taille-poids* (a, b) *et paramètres de von Bertalanffy* (L_∞, K, t_o) *pour* Atherina boyeri *et* A. presbyter *dans différentes parties de l'Atlantique et de la Méditerranée (modifié d'après Leonardos et Sinis, 2000).]*

	Authors	Study area	Maximum age (years)	*N*	*a*	*b*	L_∞ (cm TL)	*K* (year^{-1})	t_0 (years)
Atherina boyeri	Fernandez-Delgado *et al.*, 1988	Guadalquivir River, Spain	2	2510	7.0 x 10-3	2.98	-	-	-
	Creech, 1992	Aberthaw Lagoon S. Wales	2	329	3.5 x 10-6	3.27	9.2	-	-
	Leonardos, 2001	Trichonis Lake W. Greece	4	572	3.8 x 10-6	3.45	12.3	0.374	0.018
	Leonardos and Sinis, 2000	Mesolongi, Etolikon W. Greece	3	4269	4.2 x 10-3	3.15	11.6	0.240	-1.270
	Present study	Ria de Aveiro, Portugal	3	2503	3.3 x 10-3	3.35	11.6	0.099	-3.797
Atherina presbyter	Pajuelo and Lorenzo, 2000	Atlantic Canary Islands	3	1028	6.1 x 10-3	3.08	12.2	0.790	0.210
	Present study	Ria de Aveiro, Portugal	4	1169	5.5 x 10-3	3.09	15.8	0.138	-2.501

presbyter. The growth in length was generally slow and lower for *A. boyeri* than for *A. presbyter*, except during the juvenile period. Atherinids, in general, experienced a fast early growth rate through the first year of age (Fernandez-Delgado *et al*., 1988; Creech, 1992; Leonardos and Sinis, 2000), after which the annual growth rate drops rapidly, resulting of less energy available for somatic growth associated to sexual maturity (Pajuelo and Lorenzo, 2000). In the first year of life, *A. boyeri* reached approximately two third of the maximum length. The same result was obtained to Greek Mediterranean lagoons (Leonardos and Sinis, 2000). *A. presbyter* reached less than half of maximum length in the first year of life, opposing to 60% registered in the Canary Islands (Lorenzo and Pajuelo, 1999) (Tab. IV). The abiotic and biotic latitude differences, especially the temperature and productivity, may influence the low growth in Aveiro lagoon.

Along their lifespan, *A. boyeri* and *A. presbyter* depend on high productive systems, such as coastal lagoons. The length-weight relationship denoted high energetic storage for both species, however, significantly higher for the resident species, *A. boyeri*, than for the marine juvenile migrant species, *A. presbyter*. Coastal lagoons and lakes provide higher productivity than rivers. Fish occurring in these systems exhibit high energetic storage. For *A. boyeri* the b value was very close to the values established in the Atlantic Aberthaw lagoon (Creech, 1992), in the Mediterranean Mesolongi and Etolikon lagoons (Leonardos and Sinis, 2000) and in the Mediterranean lake Trichonis (Leonardos, 2001). In contrast, in Guadalquivir river, the *b* value was the lowest (Tab. IV). The *A. presbyter b* value was very similar in the Atlantic Canary Islands (Pajuelo and Lorenzo, 2000), in the south limit of the species distribution (Tab. IV).

The biometric otolith analysis showed that the otolith growth followed the fish growth independently of the species or the maximum length that each species can reach. However, as well as for the fish length/weight, the significantly difference between *A. boyeri* and *A. presbyter* otolith length/weight relationship contribute to distinguish the two species. Most growth studies on sand smelts have used otoliths or statistical methods, rarely scales. In this study, the coincided results obtained with the two methods together (otoliths and scales) and made by two people were used to minimise errors of age recordings in order to produce more trustworthy results, although not infallible.

The age and length composition of both species were quite different. The estimated L_∞ (11.6 cm for *A. boyeri* and 15.8 cm for *A. presbyter*) was in close agreement with the maximum length recorded ($L_{max} = 11.6$ cm and $L_{max} = 15.1$ cm, respectively). The theoretical maximum length values were reasonably higher than the maximum sampled size. In *A. boyeri*, L_∞ was similar in the Greek Mediterranean lagoons (Leonardos and Sinis, 2000) and deeply higher than in Wales (Aberthaw lagoon) (Creech, 1992). In contrast, the Mediterranean lake system (Leonardos, 2001) exhibited a maximum value of L_∞ (Tab. IV). For *A. presbyter*, L_∞ was higher than in the Atlantic Canary Islands (Pajuelo and Lorenzo, 2000).

A. boyeri and *A. presbyter* are sympatric species that might occur at the same space and in the same time. Both species showed similar macroscopic shape, leading to a generalised difficulty on species identification through the conventional taxonomic identification. Furthermore, on the basis of morpho-anatomical parameters, the sand smelt species is viewed as a highly polymorphic complex (Trabelsi *et al*., 2002a, 2002b). Thus, further studies on biometric, biochemical and genetic investigations in the lagoon will be needed to deal with this problem with more severity. Using the tools that were available for this study, and with conscious of some limitations of the methods, and as a preliminary work, this study allowed to distinct ecological behaviour and biological characteristics between species. The abundance and distribution per space and time by length and age, the abiotic preference during the lifespan, the fish and otolith length-weight relationships and the age and growth parameters were markedly distinct in both species. Thus, some of these ecological and biological parameters can be generally useful as accessory tools in the taxonomic identification of the atherinids species.

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